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FRAGMENTS OF SCIENCE

FOR

UNSCIENTIFIC PEOPLE:

A SERIES OF DETACHED ESSAYS, LECTURES, AND REVIEWS.

BY

JOHN TYNDALL, LL. D., F. R. S.,

AUTHOR OF "HEAT AS A MODE OF MOTION," "LECTURES ON SOUND," ETC., ETC.

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PREFACE.

My motive in writing these papers was mainly that which prompted the publication of my Royal Institution lectures; a desire, namely, to extend sympathy for science beyond the limits of the scientific public.

The fulfilment of this desire has caused a temporary and sometimes reluctant deflection of thought from the line of original research. But considering the result aimed at, and in part I trust achieved, I do not regret the price paid for it.

I have carefully looked over all the articles here printed, added a little, omitted a little—in fact, tried as far as my time permitted to render the work presentable. Most of the essays are of a purely scientific character, and from those which are not, I have endeavored, without veiling my convictions, to exclude every word that could cause needless irritation.

From America the impulse came which induced me to gather these "Fragments" together, and to my friends in the United States I dedicate them.

John Tyndall.

Athenæum Club: *March*, 1871.

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the moral sentiment, and by them the divine idea itself is exalted and diffused.

I have said that the Museum and the École Polytechnique were, for the theoretic part of science, the only two foci of illumination in France.

Our organization, indeed, did not permit of any others up to the present time. The *École Normale supérieure* has been too long an almost exclusively literary school to have any influence in the past ascribed to it. Even recently the skilful physicist Pouillet was its first and only representant in the Academy of Sciences; while the philosophers, the historians, and the literary men whom it has formed, are to be found in great numbers in the other classes of the Institute.

Medicine being, unhappily, much more an art than a science, the action of the Faculties which have dispensed a knowledge of it has not been of sensible account.

The *Conservatoire des Arts et Métiers* has only served for the progress of industry. As to our Faculties, life has been always wanting to them through many causes, but principally, as regards science, through the insufficience of material means. Under pain of scientific downfall, the state ought to have employed all possible means to convert our Museum, our École Polytechnique, and their annexes, and all other establishments of instruction, into nurseries of philosophers and discoverers.

By this means alone could France maintain the height of her mission, and preserve the preëminence which she had so justly acquired, and which was contested by no other nation fifty or sixty years ago. Unhappily, nothing of this kind has taken place. The mournful truth is, that the *Museum and the École Polytechnique* produce investigators no longer. These two establishments have never ceased to have for masters illustrious professors. Whatever may happen, a country like France will always produce great scientific individualities, but from these establishments no longer issue, as formerly, men devoted to the free exercise of thought, and to the disinterested study of Nature. At one time the majority of the foremost disciples of the École Polytechnique followed the career of mathematical and physical science, and of the higher studies generally. In our day this fact is only a rare exception. It is not that the pupils of this great school are less numerous than formerly, or less capable than their predecessors, the Maluses, the Poissons, the Fresnels, to render their country illustrious by fruitful discoveries, but the course of events invites them to carry the fruit of their studies into the operations of industry, such as the working of mines, the construction of railways, etc.

Circumstances of another nature, but which connect themselves with the same short-sightedness and the same errors, have enfeebled the Museum, and compromised the fertility of its instruction and of its labors. The penury of its material resources, the diminution of situations, the suppression of chairs, galleries and laboratories dilapidated, are so many causes which have placed the natural sciences in our day beyond the reach of the most decided abilities.

It was not comprehended that this displacement of the energy of the École Polytechnique created in the nation, to the prejudice of science, a vast gap, which would have [illegible] Revolution, the France of 1792 multiplied he [illegible] by the genius of invention, and saw rise for he [illegible] the time of need men who, it may be sai [illegible] supreme victory.

"The Convention," says Arago, "had decreed the n [illegible] men. Nothing less was necessa [illegible] the hurricane which from all poin [illegible] was about to break upon France. A cry o [illegible] which carried discouragement in [illegible] The arsenals were nearly empty. N [illegible] arms and munitions required by th [illegible] To make good this want of foresigh [illegible] calculated treason of the ancien [illegible] human power.

"[illegible] powder.

"[illegible] principal basis of the gunpowde [illegible] saltpetre of India, a resource whic [illegible] relied upon.

"[illegible]

"Copper enters largely into the alloy whereof they a formed. Now the mines of France produce copper onl in insignificant quantities. Sweden, England, Russi India, whence we had previously derived this metal, wer closed to us.

"We wanted steel.

"It came to us from foreign countries; the art of making it was unknown in our forges and our workshops. In the first reunion of *savants d'élite* which had been convoked, the question of the fabrication of powder, first in importance and first in difficulty, overpowered all minds.

The experienced members of the Government did not believe it to be soluble. 'Where,' they asked in despair, 'is saltpetre to be found?' 'On our proper soil,' answered Monge without hesitation; 'stables, cellars, and low places contain more of it than you have any notion of.' It was while feeling the infinite resources of genius when united to an ardent patriotism Monge exclaimed, 'We can obtain nitrous earth, and three days afterward we can charge from it our cannons.'"

We also, since the 4th of September, have had some sublime exclamations, but how soon they touched the ridiculous! That of Monge, on the contrary, remains sublime.

"Methodical and simple instructions," continues Arago, were freely distributed through all parts of the republic, and each citizen was able in some degree to practise an art which up to this time had been reputed very difficult.

"France became a manufactory of gunpowder.

"Bell-metal is an alloy of copper and tin, but in proportions not suitable for arms of war. Chemistry discovered new methods of separating the two metals.

"The art of making steel was unknown, but it was then and there created. The sabre, the sword, the bayonet, the lance, the gun-barrel, will be fabricated henceforth with the steel of France.

"The preparation of leather for boots and shoes required whole months of labor; such long delays could not be reconciled with the needs of our soldiers, and the art of tanning received unhoped-for improvements. Henceforth the months will be replaced by days.

in the pursuit of this object. The faith in such a consummation, involving as it did immense personal interest to the inventor, was extremely exciting, and every attempt to destroy this faith was met by bitter resentment on the part of those who held it. Gradually, however, as men became more and more acquainted with the true functions of machinery, the dream dissolved. The hope of getting work out of mere mechanical combinations disappeared; but still there remained for the speculator a cloud-land denser than that which filled the imagination of the Tyrolese priest, and out of which he still hoped to evolve perpetual motion. There was the mystic store of chemic force, which nobody understood; there were heat and light, electricity and magnetism, all competent to produce mechanical motions.[1] Here, then, is the mine in which we must seek our gem. A modified and more refined form of the ancient faith revived; and, for aught I know, a remnant of sanguine designers may at the present moment be engaged on the problem which like-minded men in former years left unsolved.

And why should a perpetual motion, even under modern conditions, be impossible? The answer to this question is the statement of that great generalization of modern science, which is known under the name of the Conservation of Energy. This principle asserts that no power can make its appearance in Nature without an equivalent expenditure of some other power; that natural agents are so related to each other as to be mutually convertible, but that no new agency is created. Light runs into heat; heat into electricity; electricity into magnetism; magnetism into mechanical force; and mechanical force again into light and heat. The Proteus changes, but he is ever the same; and his changes in Nature, supposing no miracle to supervene, are the expression, not of spontaneity, but of *physical neces-*

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[1] See Helmholtz—"Wechselwirkung der Naturkräfte."

sity. A perpetual motion, then, is deemed impossible, because it demands the creation of force, whereas the principle of Conservation is, no creation but infinite conversion.

It is an old remark that the law which moulds a tear also rounds a planet. In the application of law in Nature the terms great and small are unknown. Thus the principle referred to teaches us that the Italian wind gliding over the crest of the Matterhorn is as firmly ruled as the earth in its orbital revolution round the sun; and that the fall of its vapor into clouds is exactly as much a matter of necessity as the return of the seasons. The dispersion, therefore, of the slightest mist by the special volition of the Eternal, would be as much a miracle as the rolling of the Rhone over the Grimsel precipices and down Haslithal to Brientz.

It seems to me quite beyond the present power of science, to demonstrate that the Tyrolese priest, or his colleague of the Rhone valley, asked for an "impossibility" in praying for good weather; but science *can* demonstrate the incompleteness of the knowledge of Nature which limited their prayers to this narrow ground; and she may lessen the number of instances in which we "ask amiss," by showing that we sometimes pray for the performance of a miracle when we do not intend it. She does assert, for example, that, without a disturbance of natural law, quite as serious as the stoppage of an eclipse, or the rolling of the St. Lawrence up the Falls of Niagara, no act of humiliation, individual or national, could call one shower from heaven, or deflect toward us a single beam of the sun.

Those, therefore, who believe that the miraculous is still active in Nature, may, with perfect consistency, join in our periodic prayers for fair weather and for rain: while those who hold that the age of miracles is past, will refuse to join in such petitions. And if these latter wish to fall back upon such a justification, they may fairly urge that the latest conclusions of science are in perfect accordance with the doctrine of the Master Himself, which manifestly was that the distribution of natural phenomena is not affected by moral or religious causes. "He maketh His sun to rise on the evil and on the good, and sendeth rain on the just and on the unjust." Granting "the power of Free-will in man," so strongly claimed by Professor Mansel in his admirable defence of the belief in miracles, and assuming the efficacy of free prayer to produce changes in external Nature, it necessarily follows that natural laws are more or less at the mercy of man's volition, and no conclusion founded on the assumed permanence of those laws would be worthy of confidence.

It is a wholesome sign for England that she numbers among her clergy men wise enough to understand all this, and courageous enough to act up to their knowledge. Such men do service to the public character by encouraging a manly and intelligent conflict with the causes of disease and scarcity, instead of a delusive reliance on supernatural aid. But they have also a value beyond this local and temporary one. They prepare the public mind for changes which, though inevitable, could hardly, without such preparation, be wrought without violence. Iron is strong; still, water in crystallizing will shiver an iron envelope, and the more unyielding the metal is, the worse for its safety. There are men among us who would encompass philosophic speculation by a rigid envelope, hoping thereby to restrain it, but in reality giving it explosive force. If we want an illustration of this we have only to look at modern Rome. In England, thanks to men of the stamp to which I have alluded, scope is gradually given to thought for changes of aggregation, and the envelope slowly alters its form in accordance with the necessities of the time.

[1] b.

THE proximate origin of the foregoing slight article, and probably the remoter origin of the next following one, was this: Some years ago, a day of prayer and humiliation, on account of a bad harvest, was appointed by the proper religious authorities; but certain clergymen of the Church of England, doubting the wisdom of the demonstration, declined to join in the services of the day. For this act of nonconformity they were severely censured by some of their brethren. Rightly or wrongly, my sympathies were on the side of these men; and, to lend them a helping hand in their struggle against odds, I inserted the foregoing chapter in the little book mentioned on the title-page. Some time subsequently I received from a gentleman of great weight and distinction in the scientific world, and, I believe, of perfect orthodoxy in the religious one, a note directing my attention to an exceedingly thoughtful article on Prayer and Cholera in the *Pall Mall Gazette.* My eminent correspondent deemed the article a fair answer to the remarks made by me in 1861. I also was struck by the temper and ability of the article, but I could not deem its arguments satisfactory, and, in a short note to the editor of the *Pall Mall Gazette*, I ventured to state so much. This letter elicited some very able replies, and a second leading article was also devoted to the subject. In answer to all, I risked the publication of a second letter, and soon afterward, by an extremely courteous note from the editor, the discussion was closed.

Though thus stopped locally, the discussion flowed in other directions. Sermons were preached, essays were published, articles were written, while a copious correspondence occupied the pages of some of the religious newspapers. It gave me sincere pleasure to notice that the discussion, save in a few cases where natural coarseness had the upper hand, was conducted with a minimum of vituperation. The severity shown was hardly more than sufficient to demonstrate earnestness, while gentlemanly feeling was too predominant to permit that earnestness to contract itself to bigotry or to clothe itself in abuse. It was probably the memory of this discussion which caused another excellent friend of mine to recommend to my perusal the exceedingly able work which in the next article I have endeavored to review.

intellectual nature was left unsatisfied by the mere act of observation. He sought after the principle which ruled the fact. Whether this anecdote be true or not, it illustrates how the ordinary operations of Nature, which most people take for granted as perfectly plain and simple, are often those which most puzzle the scientific man. To the conception of the matter of the apple, Newton added that of the force that moved it. The falling of the apple was due to an attraction exerted mutually between it and the earth. He applied the idea of this force to suns, and planets, and moons, and showed that all their motions were necessary consequences of this attraction.

Newton, you know, was preceded by a grand fellow named John Kepler—a true working-man—who, by analyzing the astronomical observations of his master, Tycho Brahe, had actually found that the planets moved as they are now known to move. As a matter of fact, Kepler knew as much about the motion of the planets as Newton did; in fact, Kepler taught Newton and the world generally the facts of planetary motion. But this was not enough. The question arose—Why should the facts be so? This was the great question for Newton, and it was the solution of this question which renders his name and fame immortal. He proved that the planetary motions were what observation made them to be, because every particle of matter in the solar system attracts every other particle by a force which varies as the inverse square of the distance between the particles. He showed that the moon fell toward the earth, and that the planets fell toward the sun, through the operation of the same force that pulls an apple from its tree. This all-pervading force, which forms the solder of the material universe, and the conception of which was necessary to Newton's intellectual peace, is called the force of gravitation.

All force may be ultimately reduced to a push or a pull in a straight line; but its manifestations are various, and sometimes so complex as entirely to disguise its elementary constituents. Its different manifestations have received different names. Here, for example, is a magnet freely suspended. I bring the end of a second magnet near one of the ends of the suspended one—attraction is the consequence. I reverse the position of one of the magnets—repulsion follows. This display of power is called magnetic force. In the case of gravitation we have a simple attraction, in the case of magnetism attraction and repulsion always go together. Thus magnetism is a double force, or, as it is usually called, a polar force. I present a bit of common iron to the magnet, the iron itself becomes a temporary magnet, and it now possesses the power of attracting other iron. And if several pieces of iron be presented at the same time, not only will the magnet act on them, but they will also act upon each other.

This leads me to an experiment which will give you some idea of how bodies arrange themselves under the operation of a polar force. Underneath this plate of glass is placed a small magnet, and by an optical arrangement comprising a powerful lamp, a magnified image of the magnet is now cast upon the screen before you. I scatter iron filings over the glass. You already notice a certain arrangement of the particles of iron. Their free action is, however, hampered by friction. I therefore tap the glass, liberate the particles, which, as I tap, arrange themselves in these beautiful curves. This experiment is intended to make clear to you how a definite arrangement of particles —a kind of incipient structure—may result from the operation of a polar force. We shall by-and-by see far more wonderful exhibitions of the same structural action when we come to deal with the force of crystallization.

The magnetic force has here acted upon particles of matter visible to the eye. But, as already stated, there are to pierce. In Goethe, so glorious otherwise, I chiefly noticed the self-inflicted hurts of genius, as it broke itself in vain against the philosophy of Newton. For a time, Mr. Bain became my principal companion. I found him learned and practical, shining generally with a dry light, but exhibiting at times a flush of emotional strength, which proved that even logicians share the common fire of humanity. He interested me most when he became the mirror of my own condition. Neither intellectually nor socially is it good for man to be alone, and the griefs of thought are more patiently borne when we find that they have been experienced by another. From certain passages in his book I could infer that Mr. Bain was no stranger to such sorrows. Take this passage as an illustration. Speaking of the ebb of intellectual force, which we all from time to time experience, Mr. Bain says, "The uncertainty where to look for the next opening of discovery brings the pain of conflict and the debility of indecision." These words have in them the true ring of personal experience. The action of the investigator is periodic. He grapples with a subject of inquiry, wrestles with it, overcomes it, exhausts, it may be, both himself and it for the time being. He breathes a space, and then renews the struggle in another field. Now this period of halting between two investigations is not always one of pure repose. It is often a period of doubt and discomfort, of gloom and *ennui*. "The uncertainty where to look for the next opening of discovery brings the pain of conflict and the debility of indecision." Such was my precise condition in the Alps this year; in a score of words Mr. Bain has here sketched my mental diagnosis; and it was under these evil circumstances that I had to equip myself for the hour and the ordeal that are now come.

Gladly, however, as I should have seen this duty in other hands, I could by no means shrink from it. Disloyalty would have been worse than failure. In some fashion or other—feebly or strongly, meanly or manfully, on the higher levels of thought, or on the flats of commonplace—the task had to be accomplished. I looked in various directions for help and furtherance; but without me for a time I saw only "antres vast," and within me "deserts idle." My case resembled that of a sick doctor who had forgotten his art and sorely needed the prescription of a friend. Mr. Bain wrote one for me. He said, "Your present knowledge must forge the links of connection between what has been already achieved and what is now required."[1] In these words he admonished me tc review the past and recover from it the broken ends of former investigations. I tried to do so. Previous to going to Switzerland I had been thinking much of light and heat, of magnetism and electricity, of organic germs, atoms, molecules, spontaneous generation, comets, and skies. With one or another of these I now sought to reform an alliance, and finally succeeded in establishing a kind of cohesion between Thought and Light. The wish grew within me to trace, and to enable you to trace, some of the more occult operations of this agent. I wished, if possible, to take you behind the drop-scene of the senses, and to show you the hidden mechanism of optical action. For I take it to be well worth the while of the scientific teacher to take some pains, and even great pains, to make those whom he addresses copartners of his thoughts. To clear his own mind in the first place of all haze and vagueness, and then to project into language which shall leave no mistake as to his meaning—which shall leave even his errors naked—the definite ideas he has shaped. A great deal is, I think, possible to scientific exposition conducted in this way. It is possible, I believe, even before an audience like the present, to uncover to some extent the [illegible] of [illegible] and which the world of sense itself is the suggestion and justification.

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[1] Induct[illegible]

Far be it from me, however, to wish to fix you immovably in this or in any other theoretic conception. With all our belief of it, it will be well to keep the theory plastic and capable of change. You may, moreover, urge that although the phenomena occur *as if* the medium existed, the absolute demonstration of its existence is still wanting. Far be it from me to deny to this reasoning such validity as it may fairly claim. Let us endeavor by means of analogy to form a fair estimate of its force. You believe that in society you are surrounded by reasonable beings like yourself. You are perhaps as firmly convinced of this as of any thing. What is your warrant for this conviction? Simply and solely this, your fellow-creatures behave as if they were reasonable; the hypothesis, for it is nothing more, accounts for the facts. To take an eminent example: you believe that our President is a reasonable being. Why? There is no known method of superposition by which any one of us can apply himself intellectually to another so as to demonstrate coincidence as regards the possession of reason. If, therefore, you hold our President to be reasonable, it is because he behaves *as if* he were reasonable. As in the case of the ether, beyond the "*as if*" you cannot go. Nay I should not wonder if a close comparison of the data on which both inferences rest, caused many respectable persons to conclude that the ether had the best of it.

This universal medium, this light-ether as it is called, is a vehicle, not an origin of wave-motion. It receives and transmits, but it does not create. Whence does it derive the motions it conveys? For the most part from luminous bodies. By this motion of a luminous body I do not mean its sensible motion, such as the flicker of a candle, or the shooting out of red prominences from the limb of the sun. I mean an intestine motion of the atoms or molecules of the luminous body. But here a certain reserve is necessary. Many chemists of the present day refuse to speak of atoms and molecules as real things. Their caution leads them to stop short of the clear, sharp, mechanically intelligible atomic theory enunciated by Dalton, or any form of that theory, and to make the doctrine of multiple proportions their intellectual bourne. I respect the caution, though I think it is here misplaced. The chemists who recoil from these notions of atoms and molecules accept without hesitation the Undulatory Theory of Light. Like you and me, they one and all believe in an ether and its light-producing waves. Let us consider what this belief involves. Bring your imaginations once more into play and figure a series of sound-waves passing through air. Follow them up to their origin, and what do you there find? A definite, tangible, vibrating body. It may be the vocal chords of a human being, it may be an organ-pipe, or it may be a stretched string. Follow in the same manner a train of ether-waves to their source; remembering at the same time that your ether is matter, dense, elastic, and capable of motions subject to and determined by mechanical laws. What then do you expect to find as the source of a series of ether-waves? Ask your imagination if it will accept a vibrating multiple proportion—a numerical ratio in a state of oscillation? I do not think it will. You cannot crown the edifice by this abstraction. The scientific imagination, which is here authoritative, demands as the origin and cause of a series of ether-waves a particle of vibrating matter quite as definite, though it may be excessively minute, as that which gives origin to a musical sound. Such a particle we name an atom or a molecule. I think the seeking intellect when focussed so as to give definition without penumbral haze, is sure to realize this image at the last.

With a view of preserving thought continuous throughout this discourse, and of preventing either failure of knowlwith great distinctness which vessel contains the largest particles. The retina is very sensitive to differences of light, when, as here, the eye is in comparative darkness, and when the quantities of wave-motion thrown against the retina are small. The larger particles declare themselves by the greater whiteness of their scattered light. Call now to mind the observation, or effort at observation, made by our President, when he failed to distinguish the particles of mastic in Brücke's medium, and when you have done so follow me. I permitted a beam of light to act upon a certain vapor. In two minutes the azure appeared, but at the end of fifteen minutes it had not ceased to be azure. After fifteen minutes, for example, its color, and some other phenomena, pronounced it to be a blue of distinctly smaller particles than those sought for in vain by Mr. Huxley. These particles, as already stated, must have been less than $\frac{1}{100000}$th of an inch in diameter. And now I want you to submit to your imagination the following question: Here are particles which have been growing continually for fifteen minutes, and at the end of that time are demonstrably smaller than those which defied the microscope of Mr. Huxley: *what must have been the size of these particles at the beginning of their growth?* What notion can you form of the magnitude of such particles? The distances of stellar space give us simply a bewildering sense of vastness without leaving any distinct impression on the mind, and the magnitudes with which we have here to do bewilder us equally in the opposite direction. We are dealing with infinitesimals compared with which the test objects of the microscope are literally immense.

From their perviousness to stellar light and other considerations, Sir John Herschel drew some startling conclusions regarding the density and weight of comets. You know that these extraordinary and mysterious bodies sometimes throw out tails 100,000,000 of miles in length, and

50,000 miles in diameter. The diameter of our earth is 8,000 miles. Both it and the sky, and a good portion of space beyond the sky, would certainly be included in a sphere 10,000 miles across. Let us fill a hollow sphere of this diameter with cometary matter, and make it our unit of measure. To produce a comet's tail of the size just mentioned, about 300,000 such measures would have to be emptied into space. Now, suppose the whole of this stuff to be swept together and suitably compressed, what do you suppose its volume would be? Sir John Herschel would probably tell you that the whole mass might be carted away at a single effort by one of your dray-horses. In fact, I do not know that he would require more than a small fraction of a horse-power to remove the cometary dust. After this you will hardly regard as monstrous a notion I have sometimes entertained concerning the quantity of matter in our sky. Suppose a shell to surround the earth at a height above the surface which would place it beyond the grosser matter that hangs in the lower regions of the air—say at the height of the Matterhorn or Mont Blanc. Outside this shell we have the deep-blue firmament. Let the atmospheric space beyond the shell be swept clean, and let the sky-matter be properly gathered up. What is its probable amount? I have sometimes thought that a lady's portmanteau would contain it all. I have thought that even a gentleman's portmanteau—possibly his snuff-box—might take it in. And whether the actual sky be capable of this amount of condensation or not, I entertain no doubt that a sky quite as vast as ours, and as good in appearance, could be formed from a quantity of matter which might be held in the hollow of the hand.

Small in mass, the vastness in point of number of the particles of our sky may be inferred from the continuity of its light. It is not in broken patches, nor at scattered points that the heavenly azure is revealed. To the observer on the summit of Mont Blanc the blue is as uniform and coherent as if it formed the surface of the most close-grained solid. A marble dome would not exhibit a stricter continuity. And Mr. Glaisher will inform you that if our hypothetical shell were lifted to twice the height of Mont Blanc above the earth's surface, we should still have the azure overhead. Everywhere through the atmosphere those sky-particles are strewn. They fill the Alpine valleys, spreading like a delicate gauze in front of the slopes of pine. They sometimes so swathe the peaks with light as to abolish their definition. This year I have seen the Weisshorn thus dissolved in opalescent air. By proper instruments the glare thrown from the sky-particles against the retina may be quenched, and then the mountain which it obliterated starts into sudden definition. Its extinction in front of a dark mountain resembles exactly the withdrawal of a veil. It is the light then taking possession of the eye, and not the particles acting as opaque bodies, that interferes with the definition. By day this light quenches the stars; even by moonlight it is able to exclude from vision all stars between the fifth and the eleventh magnitude. It may be likened to a noise, and the stellar radiance to a whisper drowned by the noise.

What is the nature of the particles which shed this light? The celebrated De la Rive ascribes the haze of the Alps in fine weather to floating organic germs. Now, the possible existence of germs in such profusion has been held up as an absurdity. It has been affirmed that they would darken the air, and on the assumed impossibility of their existence in the requisite numbers, without invasion of the solar light, a powerful argument has been based by believers in spontaneous generation. Similar arguments have been used by the opponents of the germ theory of epidemic disease, who have triumphantly challeged an appeal to the microscope and the chemist's balance to decide the question. Such arguments are absolutely valueless. Without committing myself in the least to De la Rive's notion, without offering any objection here to the doctrine of spontaneous generation, without expressing any adherence to the germ theory of disease, I would simply draw attention to the fact that in the atmosphere we have particles which defy both the microscope and the balance, which do not darken the air, and which exist, nevertheless, in multitudes sufficient to reduce to insignificance the Israelitish hyperbole regarding the sands upon the sea-shore.

The varying judgments of men on these and other questions may perhaps be, to some extent, accounted for by that doctrine of relativity which plays so important a part in philosophy. This doctrine affirms that the impressions made upon us by any circumstance, or combination of circumstances, depend upon our previous state. Two travellers upon the same peak, the one having ascended to it from the plain, the other having descended to it from a higher elevation, will be differently affected by the scene around them. To the one Nature is expanding, to the other it is contracting, and feelings are sure to differ which have two such different antecedent states. In our scientific judgments the law of relativity may also play an important part. To two men, one educated in the school of the senses, who has mainly occupied himself with observation, and the other educated in the school of imagination as well, and exercised in the conceptions of atoms and molecules, to which we have so frequently referred, a bit of matter, say $\frac{1}{50000}$th of of an inch in diameter, will present itself differently. The one descends to it from his molar heights, the other climbs to it from his molecular low-lands. To the one it appears small, to the other large. So also as regards the appreciation of the most minute forms of life revealed by the microscope. To one of these men they naturally appear conterminous with the ultimate particles of matter, and he readily by self-compression, the magnitude and density of our sun. The earth itself offers evidence of a fiery origin; and in our day the hypothesis of Kant and Laplace receives the independent countenance of spectrum analysis, which proves the same substances to be common to the earth and sun.

Accepting some such view of the construction of our system as probable, a desire immediately arises to connect the present life of our planet with the past. We wish to know something of our remotest ancestry. On its first detachment from the central mass, life, as we understand it, could hardly have been present on the earth. How, then, did it come there? The thing to be encouraged here is a reverent freedom—a freedom preceded by the hard discipline which checks licentiousness in speculation—while the thing to be repressed, both in science and out of it, is dogmatism. And here I am in the hands of the meeting—willing to end, but ready to go on. I have no right to intrude upon you, unasked, the unformed notions which are floating like clouds, or gathering to more solid consistency in the modern speculative scientific mind. But if you wish me to speak plainly, honestly, and undisputatiously, I am willing to do so. On the present occasion—

"You are ordained to call, and I to come."

Two views, then, offer themselves to us. Life was present potentially in matter when in the nebulous form, and was unfolded from it by the way of natural development, or it is a principle inserted into matter at a later date. With regard to the question of time, the views of men have changed remarkably in our day and generation; and I must say as regards courage also, and a manful willingness to engage in open contest, with fair weapons, a great change has also occurred. The clergy of England—at all events the clergy of London—have nerve enough to listen to the strongest views which any one among us would care to utter; and they invite, if they do not challenge, men of the most decided opinions to state and stand by those opinions in open court. Let the hardiest theory be stated only in the language current among gentlemen, and they look it in the face; smiting the theory, if they do not like it, not with theologic fulmination, but with honest secular strength. With the country clergy I am told the case is different. It is right that I should say this, because the clergy of London have more than once offered me the chance of meeting them in open, honorable discussion.

Two or three years ago, in an ancient London College, I listened to such a discussion at the end of a remarkable lecture by a very remarkable man. Three or four hundred clergymen were present at the lecture. The orator began with the civilization of Egypt in the time of Joseph; pointing out that the very perfect organization of the kingdom, and the possession of chariots, in one of which Joseph rode, indicated a long antecedent period of civilization. He then passed on to the mud of the Nile, its rate of augmentation, its present thickness, and the remains of human handiwork found therein; thence to the rocks which bound the Nile valley, and which teem with organic remains. Thus in his own clear and admirable way he caused the idea of the world's age to expand itself indefinitely before the mind of his audience, and he contrasted this with the age usually assigned to the world. During his discourse he seemed to be swimming against the stream; he manifestly thought that he was opposing a general conviction. He expected resistance; so did I. But it was all a mistake: there was no adverse current, no opposing conviction, no resistance, merely here and there a half-humorous, but unsuccessful attempt to entangle him in his talk. The meeting agreed with all that had been said regarding the antiquity of the earth and of its life. They had, indeed, known it all long ago, and before you unclothed and unvarnished the notions by which it must stand or fall.

Surely these notions represent an absurdity too monstrous to be entertained by any sane mind. Let us, however, give them fair play. Let us steady ourselves in front of the hypothesis, and, dismissing all terror and excitement from our minds, let us look firmly into it with the hard sharp eye of intellect alone. Why are these notions absurd, and why should sanity reject them? The law of Relativity, of which we have previously spoken, may find its application here. These Evolution notions are absurd, monstrous, and fit only for the intellectual gibbet, in relation to the ideas concerning matter which were drilled into us when young. Spirit and matter have ever been presented to us in the rudest contrast, the one as all-noble, the other as all-vile. But is this correct? Does it represent what our mightiest spiritual teacher would call the Eternal Fact of the Universe? Upon the answer to this question all depends. Supposing, instead of having the foregoing antithesis of spirit and matter presented to our youthful minds, we had been taught to regard them as equally worthy and equally wonderful; to consider them in fact as two opposite faces of the self-same mystery. Supposing that in youth we had been impregnated with the notion of the poet Goethe, instead of the notion of the poet Young, looking at matter, not as brute matter, but as "the living garment of God;" do you not think that under these altered circumstances the law of Relativity might have had an outcome different from its present one? Is it not probable that our repugnance to the idea of primeval union between spirit and matter might be considerably abated? Without this total revolution of the notions now prevalent, the Evolution hypothesis must stand condemned; but in many profoundly thoughtful minds such a revolution has already taken place. They degrade neither member of the mysterious duality referred to; but they exalt one of them from its abasement, and repeal the divorce hitherto existing between both. In substance, if not in words, their position as regards the relation of spirit and matter is: "What God hath joined together let not man put asunder." And with regard to the ages of forgetfulness which lie between the unconscious life of the nebula and the conscious life of the earth, it is, they would urge, but an extension of that forgetfulness which preceded the birth of us all.

I have thus led you to the outer rim of speculative science, for beyond the nebulæ scientific thought has never ventured hitherto, and have tried to state that which I considered ought, in fairness, to be outspoken. I do not think this Evolution hypothesis is to be flouted away contemptously; I do not think it is to be denounced as wicked. It is to be brought before the bar of disciplined reason, and there justified or condemned. Let us hearken to those who wisely support it, and to those who wisely oppose it; and let us tolerate those, and they are many, who foolishly try to do either of these things. The only thing out of place in the discussion is dogmatism on either side. Fear not the Evolution hypothesis. Steady yourselves in its presence upon that faith in the ultimate triumph of truth which was expressed by old Gamaliel when he said: "If it be of God, ye cannot overthrow it; if it be of man, it will come to naught." Under the fierce light of scientific inquiry, this hypothesis is sure to be dissipated if it possess not a core of truth. Trust me, its existence as a hypothesis in the mind is quite compatible with the simultaneous existence of all those virtues to which the term Christian has been applied. It does not solve—it does not profess to solve—the ultimate mystery of this universe. It leaves in fact that mystery untouched. For granting the nebula and its potential life, the question, whence came they? would still remain to baffle and bewilder us. At bottom, the hypothetion, but also with black glass and layers of lamp-black, were publicly performed at the Royal Institution in the early part of 1862, and the effects at the foci of invisible rays then obtained were such as had never been witnessed previously.

In the experiments here referred to, glass lenses were employed to concentrate the rays. But glass, though highly transparent to the luminous, is in a high degree opaque to the invisible heat-rays of the electric lamp, and hence a large portion of those rays was intercepted by the glass. The obvious remedy here is to employ rock-salt lenses instead of glass ones, or to abandon the use of lenses wholly, and to concentrate the rays by a metallic mirror. Both of these improvements have been introduced, and, as anticipated, the invisible foci have been thereby rendered more intense. The mode of operating remains, however, the same, in principle, as that made known in 1862. It was then found that an instant's exposure of the face of the thermo-electric pile to the focus of invisible rays, dashed the needles of a coarse galvanometer violently aside. It is now found that on substituting for the face of the thermo-electric pile a combustible body, the invisible rays are competent to set that body on fire.

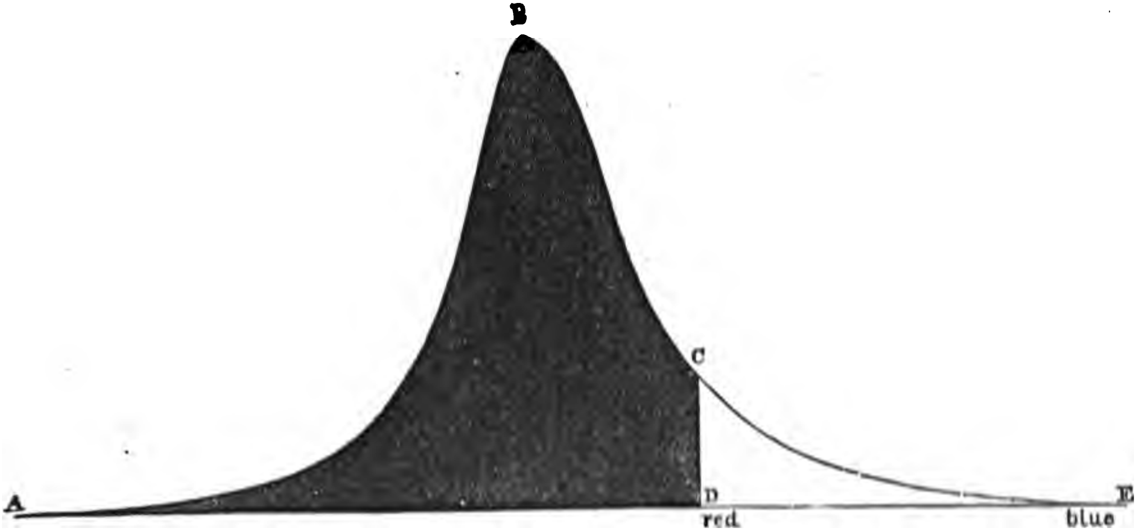
6. *Visible and Invisible Rays of the Electric Light.*

We have next to examine what proportion the non luminous rays of the electric light bear to the luminous ones. This the opaque solution of iodine enables us to do with an extremely close approximation to the truth. The pure bisulphide of carbon, which is the solvent of the iodine, is perfectly transparent to the luminous, and almost perfectly transparent to the dark rays of the electric lamp. Through the transparent bisulphide the total radiation of the lamp may be considered to pass, while through the solution of iodine only the dark rays are transmitted. Determining, then, by means of a thermo-electric pile, the total radiation, and deducting from it the purely obscure, we obtain the amount of the purely luminous emission. Experiments, performed in this way, prove that if all the visible rays of the electric light were converged to a focus of dazzling brilliancy, its heat would only be one-ninth of that produced at the unseen focus of the invisible rays.

Exposing his thermometers to the successive colors of the solar spectrum, Sir William Herschel determined the heating power of each, and also that of the region beyond the extreme red. Then drawing a straight line to represent the length of the spectrum, he erected, at various points, perpendiculars to represent the calorific intensity existing at those points. Uniting the ends of all his perpendiculars, he obtained a curve which showed at a glance the manner in which the heat was distributed in the solar spectrum. Professor Müller, of Freiburg, with improved instruments, afterward made similar experiments, and constructed a more accurate diagram of the same kind. We have now to examine the distribution of heat in the spectrum of the electric light; and for this purpose we shall employ a particular form of the thermo-electric pile, devised by Melloni. Its face is a rectangle, which by means of movable side-pieces can be rendered as narrow as desired. We can, for example, have the face of the pile the tenth, the hundredth, or even the thousandth of an inch in breadth. By means of an endless screw, this *linear* thermo-electric pile may be moved through the entire spectrum, from the violet to the red, the amount of heat falling upon the pile at every point of its march, being declared by a magnetic needle associated with the pile.

When this instrument is brought up to the violet end of the spectrum of the electric light, the heat is found to be insensible. As the pile gradually moves from the violet end toward the red, heat soon manifests itself, augmenting as we approach the red. Of all the colors of the visible spectrum the red possesses the highest heating power. On pushing the pile into the dark region beyond the red, the heat, instead of vanishing, rises suddenly and enormously in intensity, until at some distance beyond the red it attains a maximum. Moving the pile still forward, the thermal power falls, somewhat more rapidly than it rose. It then gradually shades away, but for a distance beyond the red greater than the length of the whole visible spectrum, signs of heat may be detected. Drawing a datum line, and erecting along it perpendiculars, proportional in length to the thermal intensity at the respective points, we obtain the extraordinary curve, shown on the adjacent page, which exhibits the distribution of heat in the spectrum of the electric light. In the region of dark rays, beyond the red, the curve shoots up to B, in a steep and massive peak —a kind of Matterhorn of heat, which dwarfs the portion of the diagram C D E, representing the luminous radiation. Indeed, the idea forced upon the mind by this diagram is that the light-rays are a mere insignificant appendage to the heat-rays represented by the area A B C D, thrown in as it were by Nature for the purposes of vision.

The diagram drawn by Professor Müller to represent the distribution of heat in the solar spectrum is not by any means so striking as that just described, and the reason, doubtless, is that prior to reaching the earth the solar rays have to traverse our atmosphere. By the aqueous vapor there diffused, the summit of the peak representing the sun's invisible radiation is cut off. A similar lowering of the mountain of invisible heat is observed when the rays from the electric light are permitted to pass through a film of water, which acts upon them as the atmospheric vapor acts upon the rays of the sun.



Spectrum of Electric Light.

7. *Combustion by Invisible Rays.*

The sun's invisible rays far transcend the visible ones in heating power, so that if the alleged performances of Archimedes during the siege of Syracuse had any foundation in fact, the dark solar rays would have been the philosopher's chief agents of combustion. On a small scale we can readily produce with the purely invisible rays of the electric light all that Archimedes is said to have performed with the sun's total radiation. Placing behind the electric light a small concave mirror, the rays are converged, the cone of reflected rays and their point of convergence being rendered clearly visible by the dust always floating in the air. Placing, between the luminous focus and the source of rays, our solution of iodine, the light of the cone is entirely cut away, but the intolerable heat experienced when the hand is placed, even for a moment, at the dark focus, shows that the calorific rays pass unimpeded through the opaque solution.

Almost any thing that ordinary fire can effect may be accomplished at the focus of invisible rays; the *air* at the focus remaining at the same time perfectly cold, on account of its transparency to the heat-rays. An air-thermometer, with a hollow rock-salt bulb, would be unaffected by the heat of the focus: there would be no expansion, and in the open air there is no convection. The *ether* at the focus, and not the air, is the substance in which the heat is embodied. A block of wood, placed at the focus, absorbs the heat, and dense volumes of smoke rise swiftly upward, showing the manner in which the air itself would rise, if the invisible rays were competent to heat it. At the perfectly dark focus dry paper is instantly inflamed: chips of wood are speedily burnt up: lead, tin, and zinc, are fused: and disks of charred paper are raised to vivid incandescence. It might be supposed that the obscure rays uld show no preference for black over white; but they show a preference, and, to obtain rapid combustion, the dy, if not already black, ought to be blackened. When etals are to be burned, it is necessary to blacken or herwise tarnish them, so as to diminish their reflective ower. Blackened zinc-foil, when brought into the focus f invisible rays, is instantly caused to blaze, and burns ith its peculiar purple flame. Magnesium wire flattened, r tarnished magnesium ribbon, also bursts into splendid combustion. Pieces of charcoal suspended in a receiver full of oxygen are also set on fire: the dark rays after having passed through the receiver still possessing sufficient power to ignite the charcoal, and thus initiate the attack of the oxygen. If, instead of being plunged in oxygen, the charcoal be suspended *in vacuo*, it immediately glows at the place where the focus falls.

8. *Transmutation of Rays:*[1] *Calorescence.*

Eminent experimenters were long occupied in demonstrating the substantial identity of light and radiant heat, and we have now the means of offering a new and striking proof of this identity. A concave mirror produces beyond the object which it reflects an inverted and magnified image of the object; withdrawing, for example, our iodine solution, an intensely luminous inverted image of the carbon points of the electric light is formed at the focus of the mirror employed in the foregoing experiments. When the solution is interposed, and the light is cut away, what becomes of this image? It disappears from sight, but an invisible thermograph remains, and it is only the peculiar constitution of our eyes that disqualifies us from seeing the picture formed by the calorific rays. Falling on white paper, the image chars itself out: falling on black paper, two holes are pierced in it, corresponding to the images of the two coal points: but falling on a thin plate of carbon *in vacuo*, or upon a thin sheet of platinized platinum, either *in vacuo* or in air, radiant heat is converted into light, and the image stamps itself in vivid incandescence upon both the carbon and the metal. Results similar to those obtained with the electric light have also been obtained with the invisible rays of the lime-light and of the sun.

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[1] I borrow this term from Professor Challis, "Philosophical Magazine," vol. xii., p. 521.

Before a Cambridge audience it is hardly necessary to refer to the excellent researches of Professor Stokes at the opposite end of the spectrum. The above results constitute a kind of complement to his discoveries. Professor Stokes named the phenomena which he has discovered and investigated *Fluorescence;* for the new phenomena here described I have proposed the term *Calorescence.* He, by the interposition of a proper medium, so lowered the refrangibility of the ultra-violet rays of the spectrum as to render them visible; and here, by the interposition of the platinum-foil, the refrangibility of the ultra-red rays is so exalted as to render them visible. Looking through a prism at the incandescent image of the carbon points, the light of the image is decomposed, and a complete spectrum obtained. The invisible rays of the electric light, remoulded by the atoms of the platinum, shine thus visibly forth; ultra-red rays being converted into red, orange, yellow, green, blue, indigo, and ultra-violet ones. Could we, moreover, raise the original source of rays to a sufficiently high temperature, we might not only obtain from the dark rays of such a source a single incandescent image, but from the dark rays of this image we might obtain a second one, from the dark rays of the second a third, and so on—a series of complete images and spectra being thus extracted from the invisible emission of the primitive source.[1]

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[1] On investigating the calorescence d by rays transmitted ugh glasses of various colors, it was he case of certain

9. *Deadness of the Optic Nerve to the Calorific Rays.*

The layer of iodine used in the foregoing experiments tercepted the light of the noonday sun. No trace of ght from the electric lamp was visible in the darkest om, even when a white screen was placed at the focus of e mirror employed to concentrate the light. It was ought, however, that if the retina itself were brought to the focus the sensation of light might be experienced. he danger of this experiment was twofold. If the dark ys were absorbed in a high degree by the humors of the e, the albumen of the humors might coagulate along the ne of the rays. If, on the contrary, no such high abrption took place, the rays might reach the retina with a rce sufficient to destroy it. To test the likelihood of these sults, experiments were made on water and on a solution of um, and they showed it to be very improbable that in the rief time requisite for an experiment any serious damage

ecimens of blue glass, the platinum-foil glowed with a *pink or purplish* ght. The effect was not subjective, and considerations of obvious inrest are suggested by it. Different kinds of black glass differ notably to their power of transmitting radiant heat. In thin plates some deriptions tint the sun with a greenish hue: others make it appear a owing red without any trace of green. The latter are far more diatheric than the former. In fact, carbon when perfectly dissolved, and inrporated with a good white glass, is highly transparent to the calorific ys, and by employing it as an absorbent, the phenomena of "caloresence" may be obtained, though in a less striking form than with the dine. The black glass chosen for thermometers, and intended to aborb completely the solar heat, may entirely fail in this object, if the lass in which the carbon is incorporated be colorless. To render the ulb of a thermometer a perfect absorbent, the glass ought in the first nstance to be green. Soon after the discovery of fluorescence the late r. William Allen Miller pointed to the lime-light as an illustration of xalted refrangibility. Direct experiments have since entirely confirmed he view expressed at page 210 of his work on "Chemistry," published n 1855.

tensity in the region beyond the red, but we can measure it and express it numerically. With this view the following experiment was performed. A spiral of platinum wire was surrounded by a small glass globe to protect it from currents of air; through an orifice in the globe the rays could pass from the spiral and fall afterward upon a thermo-electric pile. Placing in front of the orifice an opaque solution of iodine, the platinum was gradually raised from a low dark heat to the fullest incandescence, with the following results:

Appearance of spiral.	Energy of obscure radiation.
Dark	1
Dark, but hotter	3
Dark, but still hotter	5
Dark, but still hotter	10
Feeble red	19
Dull red	25
Red	37
Full red	62
Orange	89
Bright orange	144
Yellow	202
White	276
Intense white	440

Thus the augmentation of the electric current, which raises the wire from its primitive dark condition to an intense white heat, exalts at the same time the energy of the obscure radiation, until at the end it is fully four hundred and forty times what it was at the beginning.

What has been here proved true of the totality of the ultra-red rays is true for each of them singly. Placing our linear thermo-electric pile in any part of the ultra-red spectrum, it may be proved that a ray once emitted continues to be emitted with increased energy as the temperature is augmented. The platinum spiral so often referred to being sed to whiteness by an electric current, a brilliant spectrum was formed from its light. A linear thermo-electric e was placed in the region of obscure rays beyond the , and by diminishing the current the spiral was reduced a low temperature. It was then caused to pass through ious degrees of darkness and incandescence, with the lowing results:

Appearance of spiral.	Energy of obscure rays.
Dark	1
Dark	6
Faint red	10
Dull red	13
Red	18
Full red	27
Orange	60
Yellow	93
White	122

Here, as in the former case, the dark and bright radiaons reached their maximum together; as the one augented, the other augmented, until at last the energy of e obscure rays of the particular refrangibility here chosen ecame one hundred and twenty-two times what it was at st. To reach a white heat the wire has to pass through l the stages of invisible radiation, and in its most brilliant ondition it embraces, in an intensified form, the rays of al hose stages.

And thus it is with all other kinds of matter, as far as hey have hitherto been examined. Coke, whether brought o a white heat by the electric current, or by the oxyhyden jet, pours out invisible rays with augmented energy, s its light is increased. The same is true of lime, bricks, nd other substances. It is true of all metals which are apable of being heated to incandescence. It also holds good for phosphorus burning in oxygen. Every gush of dazzling light has associated with it a gush of invisible ra diant heat, which far transcends the light in energy. This condition of things applies to all bodies capable of being raised to a white heat, either in the solid or the molten condition. It would doubtless also apply to the luminous fogs formed by the condensation of incandescent vapors. In such cases when the curve representing the radiant energy of the body is constructed, the obscure radiation towers upward like a mountain, the luminous radiation resembling a mere spur at its base. From the very brightness of the light of some of the fixed stars we may infer the intensity of the dark radiation, which is the precursor and inseparable associate of their luminous rays.

We thus find the luminous radiation appearing when the radiant body has attained a certain temperature; or, in other words, when the vibrating atoms of the body have attained a certain width of swing. In solid and molten bodies a certain amplitude cannot be surpassed without the introduction of periods of vibration, which provoke the sense of vision. How are we to figure this? If permitted to speculate, we might ask, Are not these more rapid vibrations the progeny of the slower? Is it not really the mutual action of the atoms, when they swing through very wide spaces, and thus encroach upon each other, that causes them to tremble in quicker periods? If so, whatever be the agency by which the large swinging space is obtained, we shall have light-giving vibrations associated with it. It matters not whether the large amplitudes be produced by the strokes of a hammer, or by the blows of the molecules of a non-luminous gas, such as the air at some height above a gas-flame; or by the shock of the ether-particles when transmitting radiant heat. The result in all cases will be incandescence. Thus, the invisible waves of our filtered electric beam may be regarded as generating synchronous vibrations among the atoms of the platinum on which they impinge; but once these vibrations have atained a certain amplitude, the mutual jostling of the atoms roduces quicker tremors, and the light-giving waves fol- ow as the necessary product of the heat-giving ones.

11. *Absorption of Radiant Heat by Vapors and Odors.*

We commenced the demonstrations brought forward in his lecture by experiments on permanent gases, and we ave now to turn our attention to the vapors of volatile liquids. Here, as in the case of the gases, vast differences have been proved to exist between various kinds of molecules, as regards their power of intercepting the calorific waves. While some vapors allow the waves a comparatively free passage, the minutest bubble of other vapors, introduced into the tube already employed for gases, causes a deflection of the magnetic needle. Assuming the absorption effected by air at a pressure of one atmosphere to be unity, the followng are the absorptions effected by a series of vapors at a pressure of one-sixtieth of an atmosphere:

Name of vapor.	Absorption.
Bisulphide of carbon	47
Iodide of methyl	115
Benzol	136
Amylene	321
Sulphuric ether	440
Formic ether	548
Acetic ether	612

Bisulphide of carbon is the most transparent vapor in this list; and acetic ether the most opaque; one-sixtieth of an atmosphere of the former, however, produces forty-seven times the effect of a whole atmosphere of air, while one-sixtieth of an atmosphere of the latter produces six hundred and twelve times the effect of a whole atmosphere of air. Reducing dry air to the pressure of the acetic

IX.

ON RADIANT HEAT

IN RELATION TO THE COLOR AND CHEMICAL CONSTITUTION OF BODIES.

A DISCOURSE.

DELIVERED IN THE ROYAL INSTITUTION OF GREAT BRITAIN.

January 19, 1866.

succession of impulses than that which produces the impression of red. The vibrations of the violet are about twice as rapid as those of the red; in other words, the range of the visible spectrum is about an octave.

There is no solution of continuity in this spectrum; one color changes into another by insensible gradations. It is as if an infinite number of tuning-forks, of gradually augmenting pitch, were vibrating at the same time. But turning to another spectrum—that, namely, obtained from the incandescent vapor of silver—you observe that it consists of two narrow and intensely luminous green bands. Here it is as if two forks only, of slightly different pitch, were vibrating. The length of the waves which produce this first band is such that 47,460 of them, placed end to end, would fill an inch. The waves which produce the second band are a little shorter; it would take of these 47,920 to fill an inch. In the case of the first band, the number of impulses imparted in one second to every eye which now sees it, is 577 millions of millions; while the number of impulses imparted in the same time by the second band is 600 millions of millions. I now cast upon the screen before you the beautiful stream of green light from which these bands were derived. This luminous stream is the incandescent vapor of silver. The rates of vibration of the atoms of that vapor are as rigidly fixed as those of two tuning-forks; and to whatever height the temperature of the vapor may be raised, the rapidity of its vibrations, and consequently its color, which wholly depends upon that rapidity, remains unchanged.

The vapor of water, as well as the vapor of silver, has its definite periods of vibration, and these are such as to disqualify the vapor, when acting freely as such, from being raised to a white heat. The oxyhydrogen flame, for example, consists of hot aqueous vapor. It is scarcely visible in the air of this room, and it would be still less isible if we could burn the gas in a clean atmosphere. But the atmosphere, even at the summit of Mont Blanc, s dirty; in London it is more than dirty; and the burning dirt gives to this flame the greater portion of its present ight. But the heat of the flame is enormous. Cast-iron uses at a temperature of 2,000° Fahr. A piece of platinum s heated to vivid redness at a distance of two inches beyond the visible termination of the flame. The vapor which produces incandescence is here absolutely dark. In the flame itself the platinum is raised to dazzling whiteness, and is finally pierced by the flame. When this flame impinges on a piece of lime, we have the dazzling Drummond light. But the light is here due to the fact that when it impinges upon the solid body, the vibrations excited in that body by the flame are of periods different from its own.

Thus far we have fixed our attention on atoms and molecules in a state of vibration, and surrounded by a medium which accepts their vibrations, and transmits them through space. But suppose the waves generated by one system of molecules to impinge upon another system, how will the waves be affected? Will they be stopped, or will they be permitted to pass? Will they transfer their motion to the molecules on which they impinge, or will they glide round the molecules, through the intermolecular spaces, and thus escape?

The answer to this question depends upon a condition which may be beautifully exemplified by an experiment on sound. These two tuning-forks are tuned absolutely alike. They vibrate with the same rapidity, and mounted thus upon their resonant stands, you hear them loudly sounding the same musical note. I stop one of the forks, and throw the other into strong vibration. I now bring that other near the silent fork, but not into contact with it. Allowing them to continue in this position for four or five seconds,

> "Tout miasme contagieux a les propriétés, 1° de reproduire son analogue dans une maladie qu'il a occasionnée ; 2° de se répandre et de s'entendre à l'infini, en vertu de ce développement secondaire, c'est-à-dire, aussi longtemps qu'il existe une matière propre à recevoir le miasme, et en à produire un nouveau. Ces deux propriétés lui sont communes avec les germes des animaux et des plantes.
>
> HILDEBRAND.

XI.

ON DUST AND DISEASE.

Experiments on Dusty Air.

SOLAR light in passing through a dark room reveals its track by illuminating the dust floating in the air. "The sun," says Daniel Culverwell, "discovers atomes, though they be invisible by candle-light, and makes them dance naked in his beams."[1]

In my researches on the decomposition of vapors by light, I was compelled to remove these "atomes" and this dust. It was essential that the space containing the vapors should embrace no visible thing; that no substance capable of scattering the light in the slightest sensible degree should, at the outset of an experiment, be found in the "experimental tube" traversed by the luminous beam.

For a long time I was troubled by the appearance there of floating dust, which though invisible in diffuse daylight was at once revealed by a powerfully-condensed beam. Two tubes were placed in succession in the path of the air: the one containing fragments of glass wetted with concentrated sulphuric acid; the other, fragments of marble wetted with a strong solution of caustic potash. To my astonishment the dust passed through both. The air of the Royal Institution sent through these tubes at a rate sufficiently slow

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[1] On a day of transient shadows there is something almost magical in the rise and dissolution of the luminous beams among the scaffolding poles of the Royal Albert Hall.

4. The experiment was repeated, with the difference that the air was sent more slowly through the red-hot tube. The floating matter was totally destroyed.

5. The platinum tube was now lowered until it bordered upon a visible red heat. The air sent through it still more slowly than in the last experiment carried with it a cloud of floating matter.

If, then, the suspended matter is destroyed by a bright-red heat, much more is it destroyed by a flame, whose temperature is vastly higher than any here employed. So that the blackness introduced into a luminous beam where a flame is placed beneath it is due, as stated, to the destruction of the suspended matter. At a dull-red heat, however, and still more when only on the verge of redness, the platinum tube permitted the motes to pass freely. In the latter case the temperature was 800° or 900° Fahrenheit. This was unable to destroy the suspended matter; much less, therefore, would a platinum wire heated to 212° be competent to do so. Such a wire can only distribute the matter, not destroy it.

The floating dust is revealed by intense local illumination. It is seen by contrast with the adjacent illuminated space; the brighter the illumination the more sensible is the difference. Now, the beam employed in the foregoing experiments is not of the same brightness throughout its entire transverse section. Pass a white switch, or an ivory paper-cutter, rapidly across the beam, the impression of its section will linger on the retina. The section seems *to float* for a moment in the air as a luminous circle, with a rim much brighter than its central portion. The core of the beam is thus seen to be enclosed by an intensely-luminous sheath. An effect complementary to this is observed when the beam is intersected by the dark band from the platinum wire. The brighter the illumination the greater must be the relative darkness consequent on the withdrawal of the light.

Hence the cross-section of the sheath surrounds the dark band as a darker ring.

Oxygen, hydrogen, nitrogen, carbonic acid, so prepared as to exclude all floating particles, produce the darkness when poured or blown into the beam. Coal-gas does the same. An ordinary glass shade placed in the air with its mouth downward permits the track of the beam to be seen crossing it. Let coal-gas or hydrogen enter the shade by a tube reaching to its top, the gas gradually fills the shade from the top downward. As soon as it occupies the space crossed by the beam, the luminous track is instantly abolished. Lifting the shade so as to bring the common boundary of gas and air above the beam, the track flashes forth. After the shade is full, if it be inverted, the gas passes upward like a black smoke among the illuminated particles.

The air of our London rooms is loaded with this organic dust, nor is the country air free from its presence. However ordinary daylight may permit it to disguise itself, a sufficiently powerful beam causes dust suspended in air to appear almost as a semi-solid. Nobody could, in the first instance, without repugnance, place the mouth at the illuminated focus of the electric beam and inhale the thickly-massed dust revealed there. Nor is the repugnance abolished by the reflection that, although we do not see the floating particles, we are taking them into our lungs every hour and minute of our lives.

The Germ-Theory of Contagious Disease.

There is no respite to this contact with the floating matter of the air; and the wonder is, not that we should suffer occasionally from its presence, but that so small a portion of it, and even that but rarely diffused over large areas, should appear to be deadly to man. And what is this portion? It was some time ago the current belief that epidemic diseases generally were propagated by a kind of malaria, which consisted of organic matter in a state of *motor-decay*; that when such matter was taken into the body through the lungs, skin, or stomach, it had the power of spreading there the destroying process which had attacked itself. Such a power was visibly exerted in the case of yeast. A little leaven was seen to leaven the whole lump, a mere speck of matter in this supposed state of decomposition being apparently competent to propagate indefinitely its own decay. Why should not a bit of rotten malaria work in a similar manner within the human frame? In 1836 a very wonderful reply was given to this question. In that year Cagniard de la Tour discovered the *yeast-plant*, a living organism, which, when placed in a proper medium, feeds, grows, and reproduces itself, and in this way carries on the process which we name fermentation. By this striking discovery fermentation was connected with organic growth.

Schwann, of Berlin, discovered the yeast-plant independently about the same time; and in February, 1837, he also announced the important result that, when a decoction of meat is effectually screened from ordinary air, and supplied solely with calcined air, putrefaction never sets in. Putrefaction, therefore, he affirmed to be caused by something derived from the air, which something could be destroyed by a sufficiently high temperature. The results of Swann were confirmed by the independent experiments of Helmholtz, Ure, and Pasteur, while other methods, pursued by Schultze and by Schroeder and Dusch, led to the same result. But as regards fermentation, the minds of chemists, influenced probably by the great authority of Gay-Lussac, fell back upon the old notion of matter in a state of decay. It was not the living yeast-plant, but the dead or dying parts of it, which, assailed by oxygen, produced the fermentation. This notion was finally exploded by Pasteur. He proved that the so-called "ferments" are not such;

hat the true ferments are organized beings, which find in he reputed ferments their necessary food.

Side by side with these researches and discoveries, and rtified by them and others, has run the *germ-theory* of pidemic disease. The notion was expressed by Kircher nd favored by Linnæus, that epidemic diseases are due germs which float in the atmosphere, enter the body, and roduce disturbance by the development within the body parasitic life. While it was still struggling against reat odds, this theory found an expounder and a defender the President of this institution. At a time when most f his medical brethren considered it a wild dream, Sir Ienry Holland contended that some form of the germheory was probably true. The strength of this theory onsists in the perfect parallelism of the phenomena of conagious disease with those of life. As a planted acorn ives birth to an oak competent to produce a whole crop f acorns, each gifted with the power of reproducing its arent-tree; and as thus from a single seedling a whole rest may spring; so, it is contended, these epidemic disases literally plant their seeds, grow, and shake abroad ew germs, which, meeting in the human body their proper od and temperature, finally take possession of whole opulations. There is nothing to my knowledge in pure hemistry which resembles the power of self-multiplication ossessed by the matter which produces epidemic disease. f you sow wheat you do not get barley; if you sow smallox you do not get scarlet fever, but small-pox indefinitely ultiplied, and nothing else. The matter of each conagious disease reproduces itself as rigidly as if it were (as Iiss Nightingale puts it) dog or cat.

Parasitic Diseases of Silk-worms. Pasteur's Researches.

It is admitted on all hands that some diseases are the roduct of parasitic growth. Both in man and lower creawhile thus instructing himself that he succeeded in causing a wire carrying an electric current to rotate round a magnetic pole. This was not the result sought by Wollaston, but it was closely related to it.

The strong tendency of Faraday's mind to look upon the reciprocal actions of natural forces gave birth to his greatest discoveries; and we, who know this, should be justified in concluding that, even had Wollaston not preceded him, the result would have been the same. But in judging Davy we ought to transport ourselves to his time, and carefully exclude from our thoughts and feelings that noble subsequent life which would render simply impossible the ascription to Faraday of anything unfair. It would be unjust to Davy to put our knowledge in the place of his, or to credit him with data which he could not have possessed. Rumor and fact had connected the name of Wollaston with these supposed interactions between magnets and currents. When, therefore, Faraday in October published his successful experiment without any allusion to Wollaston, general, though really ungrounded, criticism followed. I say ungrounded because, firstly, Faraday's experiment was not that of Wollaston, and secondly, Faraday, before he published it, had actually called upon Wollaston, and not finding him at home did not feel himself authorized to mention his name.

In December Faraday published a second paper on the same subject, from which, through a misapprehension, the name of Wollaston was also omitted. Warburton and others thereupon affirmed that Wollaston's ideas had been appropriated without acknowledgment, and it is plain that Wollaston himself, though cautious in his utterance, was also hurt. Censure grew till it became intolerable. "I hear," writes Faraday to his friend Stodart, "every day more and more of these sounds, which, though only whispers to me, are, I suspect, spoken aloud among scientific men." He might have written explanations and defences, but he went straighter to the point. He wished to see the principals face to face—to plead his cause before them personally. There is a certain vehemence in his desire to do this. He saw Wollaston, he saw Davy, he saw Warburton; and I am inclined to think that it was the irresistible candor and truth of character which these *viva voce* defences revealed, as much as the defences themselves, that disarmed resentment at the time.

As regards Davy, another cause of dissension arose in 1823. In the spring of that year Faraday analyzed the hydrate of chlorine, a substance once believed to be the element chlorine, but proved by Davy to be a compound of that element and water. The analysis was looked over by Davy, who then and there suggested to Faraday to heat the hydrate in a closed glass tube. This was done, the substance was decomposed, and one of the products of decomposition was proved by Faraday to be chlorine liquefied by its own pressure. On the day of its discovery he communicated this result to Dr. Paris. Davy, on being informed of it, instantly liquefied another gas in the same way. Having struck thus into Faraday's inquiry, ought he not to have left the matter in Faraday's hands? I think he ought. But, considering his relation to both Faraday and the hydrate of chlorine, Davy, I submit, may be excused for thinking differently. A father is not always wise enough to see that his son has ceased to be a boy, and estrangement on this account is not rare; nor was Davy wise enough to discern that Faraday had passed the mere assistant stage and become a discoverer. It is now hard to avoid magnifying this error. But had Faraday died or ceased to work at this time, or had his subsequent life been devoted to money-getting instead of to research, would anybody now dream of ascribing jealousy to Davy? Assuredly not. Why should he be jealous? His rep[illegible] this short, you will, in all likelihood, have enriched your experience in many ways without any special direction from me.

Well, the magnet attracts the nail, and that nail attracts a second one. This proves that the nail in contact with the magnet has had the magnetic quality developed in it by that contact. If it be withdrawn from the magnet, its power to attract its fellow-nail ceases. Contact, however, is not necessary. A sheet of glass or paper, or a space of air, may exist between the magnet and the nail; the latter is still magnetized, though not so forcibly as when in actual contact. The nail then presented to the magnet is itself a temporary magnet. That end which is turned toward the magnetic pole has the opposite magnetism of the pole which excites it; the end most remote from the pole has the same magnetism as the pole itself, and between the two poles the nail, like the magnet, possesses a magnetic equator.

Conversant as you now are with the theory of magnetic fluids, you have already, I doubt not, anticipated me in imagining the exact condition of the iron under the influence of the magnet. You picture the iron as possessing the neutral fluid in abundance, you picture the magnetic pole, when brought near, decomposing the fluid; repelling the fluid of a like kind with itself, and attracting the unlike fluid; thus exciting in the parts of the iron nearest to itself the opposite polarity. But the iron is incapable of becoming a permanent magnet. It only shows its virtue as long as the magnet acts upon it. What, then, does the iron lack which the steel possesses? It lacks coercive force. Its fluids are separated with ease, but, once the separating cause is removed, they flow together again and neutrality is restored. Your imagination must be quite nimble in picturing these changes. You must be able to see the fluids dividing and reuniting according as the magnet is brought near or withdrawn. Fixing a definite pole in your imagination, you must picture the precise arrangement of the two fluids with reference to this pole. And you must not only be well drilled in the use of this mental imagery yourself, but you must be able to arouse the same pictures in the minds of your pupils, and satisfy yourself that they possess this power of placing actually before themselves magnets and iron in various positions, and describing the exact magnetic state of the iron in each particular case. The mere facts of magnetism will have their interest immensely augmented by an acquaintance with those hidden principles whereon the facts depend. Still, while you use this theory of magnetic fluids to track out the phenomena and link them together, be sure to tell your pupils that it is to be regarded as a symbol merely—a symbol, moreover, which is incompetent to cover all the facts,[1] but which does good practical service while we are waiting for the actual truth.

This state of excitement into which the soft iron is thrown by the influence of the magnet, is sometimes called "magnetization by influence." More commonly, however, the magnetism is said to be "induced" in the soft iron, and hence this way of magnetizing is called "magnetic induction." Now, there is nothing theoretically perfect in Nature: there is no iron so soft as not to possess a certain amount of coercive force, and no steel so hard as not to be capable, in some degree, of magnetic induction. The quality of steel is in some measure possessed by iron, and the quality of iron is shared in some degree by steel. It is in virtue of this latter fact that the unmagnetized darningself back against my chair, and gazed listlessly out of the window. While thus engaged, the table was rudely pushed. Attention was drawn to the wine, still oscillating in the glasses, and I was asked whether that was not convincing. I readily granted the fact of motion, and began to feel the delicacy of my position. There were several pairs of arms upon the table, and several pairs of legs under it; but how was I, without offence, to express the conviction which I really entertained? To ward off the difficulty, I again turned a wine-glass upside down and rested my ear upon it. The rim of the glass was not level, and the hair on touching it caused it to vibrate and produce a peculiar buzzing sound. A perfectly candid and warm-hearted old gentleman at the opposite side of the table, whom I may call A., drew attention to the sound, and expressed his entire belief that it was spiritual. I, however, informed him that it was the moving hair acting on the glass. The explanation was not well received, and X., in a tone of severe pleasantry, demanded whether it was the hair that had moved the table. The promptness of my negative probably satisfied him that my notion was a very different one.

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[1] This theory breaks down when applied to diamagnetic bodies, which are repelled by magnets. Like soft iron, such bodies are thrown into a state of temporary excitement in virtue of which they are repelled, but any attempt to explain such a repulsion by the decomposition of a fluid will demonstrate its own futility.

The superhuman power of the spirits was next dwelt upon. The strength of man, it was stated, was unavailing in opposition to theirs. No human power could prevent the table from moving when they pulled it. During the evening this pulling of the table occurred, or rather was attempted, three times. Twice the table moved when my attention was withdrawn from it; on a third occasion, I tried whether the act could be provoked by an assumed air of inattention. Grasping the table firmly between my knees, I threw myself back in the chair, and waited, with eyes fixed on vacancy, for the pull. It came. For some seconds it was pull spirit, hold muscle; the muscle, however, prevailed, and the table remained at rest. Up to the present moment, this interesting fact is known only to the particular spirit in question and myself.

A species of mental scene-painting, with which my own pursuits had long rendered me familiar, was employed to figure the changes and distribution of spiritual power. The spirits were provided with atmospheres, which combined with and interpenetrated each other, considerable ingenuity being shown in demonstrating the necessity of *time* in effecting the adjustment of the atmospheres. In fact, just as in science, the senses, time, and space, constituted the conditions of the phenomena. A rearrangement of our positions was proposed and carried out; and soon afterward my attention was drawn to a scarcely sensible vibration on the part of the table. Several persons were leaning on the table at the time, and I asked permission to touch the medium's hand. "Oh, I know I tremble," was her reply. Throwing one leg across the other, I accidentally nipped a muscle, and produced thereby an involuntary vibration of the free leg. This vibration, I knew, must be communicated to the floor, and thence to the chairs of all present. I therefore intentionally promoted it. My attention was promptly drawn to the motion; and a gentleman beside me, whose value as a witness I was particularly desirous to test, expressed his belief, that it was out of the compass of human power to produce so strange a tremor. "I believe," he added earnestly, "that it is entirely the spirits' work." "So do I," added, with heat, the candid and warm-hearted old gentleman A. "Why, sir," he continued, "I feel them at this moment shaking my chair." I stopped the motion of the leg. "Now, sir," A. exclaimed, "They are gone." I began again, and A. once more ejaculated. I could, however, notice that there were doubters present, who did not quite know what to think of the manifestations. I saw their perplexity; and, as there was sufficient reason to believe that the disclosure of the secret would simply provoke anger, I kept it to myself.

SPENCER'S SYSTEM OF PHILOSOPHY.

THE PHILOSOPHY OF EVOLUTION.

By HERBERT SPENCER.

This great system of scientific thought, the most original and important mental undertaking of the age, to which Mr. Spencer has devoted his life, is now well advanced, the published volumes being: *First Principles*, *The Principles of Biology*, two volumes, and *The Principles of Psychology*, vol. I., which will be shortly printed.

This philosophical system differs from all its predecessors in being solidly based on the sciences of observation and induction; in representing the order and course of Nature; in bringing Nature and man, life, mind, and society, under one great law of action; and in developing a method of thought which may serve for practical guidance in dealing with the affairs of life. That Mr. Spencer is the man for this great work will be evident from the following statements:

"The only complete and systematic statement of the doctrine of Evolution with which I am acquainted is that contained in Mr. Herbert Spencer's 'System of Philosophy;' a work which should be carefully studied by all who desire to know whither scientific thought is tending."—T. H. Huxley.

"Of all our thinkers, he is the one who has formed to himself the largest new scheme of a systematic philosophy."—Prof. Masson.

"If any individual influence is visibly encroaching on Mills in this country, it is his."—*Ibid.*

"Mr. Spencer is one of the most vigorous as well as boldest thinkers that English speculation has yet produced."—John Stuart Mill.

"One of the acutest metaphysicians of modern times."—*Ibid.*

"One of our deepest thinkers."—Dr. Joseph D. Hooker.

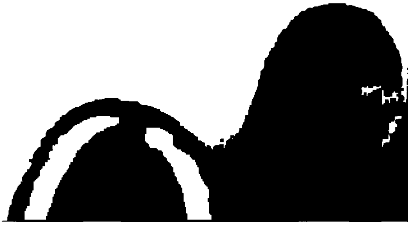
It is questionable if any thinker of finer calibre has appeared in our country."—George Henry Lewes.

"He alone, of all British thinkers, has organized a philosophy."—*Ibid.*

"He is as keen an analyst as is known in the history of philosophy; I do not except either Aristotle or Kant."—George Ripley.

"If we were to give our own judgment, we should say that, since Newton, there has not in England been a philosopher of more remarkable speculative and systematizing talent than (in spite of some errors and some narrowness) Mr. Herbert Spencer."—*London Saturday Review.*

"We cannot refrain from offering our tribute of respect to one who, whether for the extent of his positive knowledge, or for the profundity of his speculative insight, has already achieved a name second to none in the whole range of English philosophy, and whose works will worthily sustain the credit of English thought in the present generation."—*Westminster Review.*



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